CHAPTER 5

Loss Aversion in Option Pricing: Integrating Two Nobel Models

As we discussed, loss aversion is the central concept of the prospect theory and behavioral economics (Kahneman and Tversky, 1979, 2000). It suggests that losses loom larger than gains. For example, losing $1,000 may cause a stronger mental response in an investor's mind than gaining the same amount of wealth. The empirical finding on loss aversion has been widely demonstrated, thus it is the classic principle of behavioral economics and the backbone for Kahneman's 2002 Nobel Prize.

Option pricing is a typical research and practical topic in financial economics. It refers to the valuation of options that are the right (not commitment) to buy or sell the underlying asset at a specific price in a fixed future date. The Black-Scholes model on option pricing (1973) has pushed the popularity of the option pricing research to a new level. Both the Black-Scholes model and prospect theory have won Noble Prizes in economics.

However, do these two important topics connect? Little literature or practice has documented the existence of loss aversion in option pricing. In this chapter, we will provide repeatable empirical evidence to demonstrate that the two topics are connected. In other words, loss aversion exists in option pricing. I do this with the help of real-time computer algos.

DEMONSTRATING LOSS AVERSION WITH COMPUTER ALGOS

We use computer algos to demonstrate a real-time empirical finding that loss aversion (Kahneman and Tversky, 1979, 2000; Ye, 2005) may be

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observed in option pricing (Black and Scholes, 1973; Hull, 2008). This empirical finding occurs on strike-on-spot prices, which are the closest strike prices to the spot prices of the underlying assets.

The strike-on-spot prices are close to the at-the-money strike prices but the two are different. At-the-money strike prices suggest that the spot prices are equal to the strike prices. As the spot prices in reality change all the time, it is rare to find that at-the-money strike prices and spot prices are the same.

The context to discover loss aversion is with call and put options.[1] For call options, traders feel a gain when a strike price goes up, whereas they suffer a loss when the strike price goes down.

The computer algos are Web-based computer programs that collect real-time empirical data from a randomly selected sample with 32 tickers. The 32 tickers have call premium changes for loss and gain conditions. Call premiums reflect traders' mental evaluation to future events. Hence, the changes of call premiums would reflect the mental responses to the loss or gain conditions.

After collecting the data in real time, real-time t-tests are conducted on the data to check the significant difference in call premium changes between the loss and gain conditions (loss/gain ratio). The results have repeatedly demonstrated that loss aversion does exist in option pricing.

Here is an example. The data in Table 5.1 were captured on November 27, 2009, at 09:09:40:26. These data are generated by proprietary computer algos. A real-time significance test was conducted with this result: The mean of the ratios = 3.09; $std = 3.76$; $t\ (31) = 3.14$; p-value = 0.00084481. The result suggests that traders' mental response as call premium changes due to asset price drops is significantly larger than their response to the same price increases. This real-time trial may be repeated many times by refreshing the URL that triggers the computing. Therefore, the real-time computer algos have repeatedly demonstrated the empirical finding of loss aversion in option pricing.

We also found evidence for the case of put options. The data show that the put premium changes due to losses (price up) is significantly larger than the put premium change due to gains (price down).

If we change the locus of forming losses and gains conditions, namely, shifting the locus of strike-on-spot prices, the effect may disappear. So the moderator for loss aversion in option pricing may be the distance between the strike price and the current spot price of the underlying asset. The loss aversion may disappear when the strike price of the option is distant from the current spot price. This is consistent with the empirical finding in other contexts of the locus effect of loss aversion (see previous chapter). The locus effect of loss aversion suggests that the strength of loss aversion may be affected by the locus of evaluation on self or others.

TABLE 5.1 Real-Time Empirical Evidence—Call Options

Tick	Premium Change Due to Loss	Due to Same Gain	Ratio
ACH	0.35	0.40	0.87
ACI	0.55	0.35	1.57
ACL	1.70	1.67	1.02
GOOG	5.15	3.75	1.37
MSFT	1.40	0.32	4.38
ACO	1.75	0.95	1.84
ACS	3.80	1.35	2.81
IBM	4.21	2.46	1.71
MMM	2.90	0.55	5.27
C	0.92	0.23	4.00
CA	1.83	0.52	3.52
CAB	1.70	0.50	3.40
MOT	0.86	0.39	2.21
CAH	4.39	2.46	1.78
CAJ	5.50	0	0
CAL	0.80	0.50	1.60
CAT	3.19	0.76	4.20
CAM	1.95	1.15	1.70
FAZ	0.48	0.32	1.50
CAR	1.95	0.60	3.25
ORCL	0.57	0.28	2.04
DCI	3.65	0.55	6.64
T	0.70	0.35	2
CBS	0.88	0.26	3.38
BAC	0.64	0.34	1.88
AIG	0.46	0.34	1.35
L	5.20	0.9	5.78
IBM	4.21	2.46	1.71
INTC	4.23	0.19	2.26
GS	2.60	1.89	1.38
FAZ	0.48	0.32	1.50
FAS	0.45	0.55	0.82

VISUALIZING THE FINDINGS

We may visualize the finding with an options table as shown in Figure 5.1, which is captured from the Yahoo!Finance web site. The spot price of ticker C (for Citigroup, Inc.) is 4.06. The strike-on-spot price is 4, which is the closest price to the spot price. The computer algos automatically

Options Get

View By Expiration; Nov 09 | Dec 09 | Jan 10 | Mar 10 | Jun 10 | Jan 11

CALL OPTIONS Expire at close Fri, Nov 20, 2009

Strike	Symbol	Last	Chg	Bid	Ask	Vol	Open int
1.00	CKT X	3.00	0.00	3.00	3.10	8	165
2.00	CKU X	2.04	↓0.01	2.04	2.07	48	753
3.00	CKV X	1.05	↑0.02	1.05	1.07	1,475	9,454
4.00	CKW X	0.17	↓0.01	0.16	0.17	18,742	144,926
5.00	CKP X	0.02	0.00	0.01	0.02	9,571	434,916
6.00	CKX X	0.01	0.00	N/A	0.01	980	116,595
7.00	CKG X	0.01	0.00	N/A	0.01	1	10,718
8.00	CKH X	0.01	0.00	N/A	0.02	100	5,950
9.00	CKI X	0.02	0.00	N/A	0.01	17	472

PUT OPTIONS Expire at close Fri, Nov 20, 2009

Strike	Symbol	Last	Chg	Bid	Ask	Vol	Open int
2.00	CWU X	0.01	0.00	N/A	0.01	100	792
3.00	CWV X	0.01	0.00	N/A	0.01	1,634	89,839
4.00	CWW X	0.11	↓0.02	0.10	0.11	18,358	353,379
5.00	CWP X	0.98	↑0.02	0.95	0.97	9,570	118,214
6.00	CWX X	1.97	0.00	1.93	1.96	736	6,164
7.00	CWG X	2.96	0.00	2.93	2.96	29	394
8.00	CWH X	3.35	0.00	3.90	4.00	20	20

FIGURE 5.1 Options Data for Citigroup (C)

search for the strike-on-spot price using a proprietary sorting and comparing algo.

If the strike price changes from 4 to 5, the associated call option premium would change from 0.17 to 0.02. Thus the change in value is 0.15. This is a gain condition as profit may increase due to the strike price change. For the loss condition, when the strike price drops from 4 to 3, the call premium changes from 0.17 to 1.05, with the value of the change being 0.88. The change in the call premiums indicates traders' mental response to the underlying stock price change.

With the call premium change for the loss condition being 0.88, and that of the gain condition 0.15, we may compute the loss versus gain ratio,

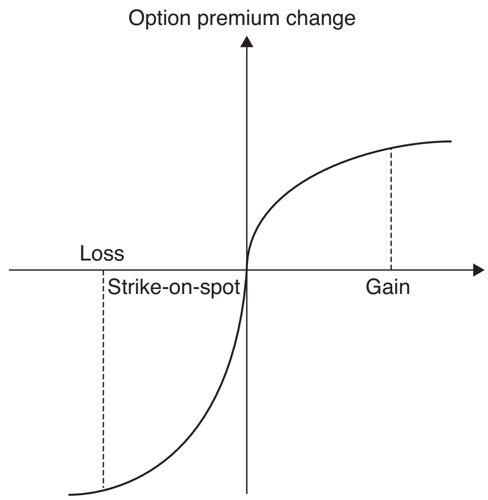

FIGURE 5.2 Loss Aversion Effect in Option Pricing

namely, loss/gain ratio = 0.88/0.15 = 5.87. This is much larger than 1. Therefore, we conclude in this case that loss aversion exists in option pricing.

Let us look at a case of put options. Similarly, traders feel gains as price goes down for a put option at the strike-on-spot price. For example, when the price goes down from 4 to 3, the put premium change is .11 – .01 = 0.1. When the price goes up from 4 to 5, traders feel a loss. Thus the put change is 0.98 – 0.11 = 0.87. The loss aversion ratio is .87/.11 = 7.9, where the put premium change due to losses is much larger than the change due to gains. Figure 5.2 visualizes the loss aversion effect in option pricing with a typical loss aversion diagram.

COMPUTER ALGOS FOR THE FINDING

The computer algos behind this finding are triggered by a URL from the Web. Let us look at part of the algos. In Part Four of the book, we elaborate the detailed infrastructure and technologies for developing these computer algos. Ideally, the reader may want to go through Part Four before diving into the following computer algos.

The computer algos are triggered by a call to testLossGainArr() that takes in a sample of 32 tickers and loop through each ticker to call testLossGain(). The result is displayed as data entries in an HTML table.

The function testLossGain() gets all the strike prices and the current spot price at first; then compares the spot price against the array of strike prices to find out the strike-on-spot price; and then it calls getLossGainNearCurrentPrice() that computes the option premium changes due to losses and gains.Yeswici.com provides a utility to test the effect with real-time data. Please e-mail info@yeswici.com for the specific utility.

```
testLossGainArr();
function testLossGainArr()
{
  $arr =
  array("ACH","ACI","ACL","ACM","ACN","ACO", "ACS","BYI","BZ","C","CA","CAB","CAG",
  "CAH","CAJ","CAL","CAT","CAM","FAZ","CAR","DBS","DCI","SPY","QQQQ","BAC", "AIG",
  "QQQQ","IBM","BAC","GS","GOOG","FAS");

  echo '<link href="../style.css" rel="stylesheet" type="text/css">';
  echo "<b>Empirical evidence for loss aversion in option pricing - case of call
  options</b>";
  echo "<table border=1>";
  echo "<tr><td>Tick</td><td>premium change due to loss</td><td>due to same
  gain</td></tr>";
  for($i=0; $i<sizeof($arr); $i++)
  {
      testLossGain($arr[$i], "");
  }
  echo "</table>";
 }

function testLossGain($tick, $m)
{
  echo "<tr><td>$tick</td>";
  $arr_c_strike_premium = getCallOptionStrikesLastPriceByMonth($tick, $m);
  $currentAssetPrice = getCurrentPrice($tick);
  $closestStrike = getClosetStrikeToAssetPrice($currentAssetPrice,
   $arr_c_strike_premium[0]);
  $keyClosestStrike = getKey($arr_c_strike_premium[0],$closestStrike);
  $nearLossGain = getLossGainNearCurrentPrice($keyClosestStrike,
  $arr_c_strike_premium[1]);
  //print_r($arr_c_strike_premium);
}

function getLossGainNearCurrentPrice($k, $arr)
{
  $arr_r[0] = $arr[$k-1] - $arr[$k]; //loss
  $arr_r[1] = $arr[$k] - $arr[$k+1]; //gain
  echo "<td>$arr_r[0]</td><td>$arr_r[1]</td></tr>";
}

function getKey($arr, $val)
{
  for($i=0; $i<sizeof($arr); $i++)
  {
    if($val == $arr[$i])
    {
     $k = $i;
    }
  }
  return $k;
}
```

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```
function getClosetStrikeToAssetPrice($cp, $arr_strike)
{
  $s = 0;
  $arr_d = array();
  for($i=0; $i<sizeof($arr_strike); $i++)
  {
      $sp = $arr_strike[$i];
      $diff = abs($cp - $sp);
      $arr_d[$i] = $diff;
  }
  sort($arr_d);
  $s = $cp - $arr_d[0];
  $k = array_search($s, $arr_strike);
  $z = in_array($s, $arr_strike);
  if($k==NULL && !$z)
  {
      $s = $arr_d[0] + $cp;
  }
  return $s;
}

function getCallOptionStrikesLastPriceByMonth($tick, $m)
{
  $arr = array();
  $res = getOptionPageByMonth($tick, $m);
  $size = getSize($res);
  $arr_calls = parseVol2PArr($res, $size);
  $tot_calls = array_sum($arr_calls);
  $arr_strikes = getStrikes($res, $size);
  $arr_premium = getPremiums($res, $size);
  $arr[0] = $arr_strikes;
  $arr[1] = $arr_premium;
  return $arr;
}
```

To reproduce the finding, a reader with extensive computer programming experience may integrate the algos with real-time ticker data feeds. The reader has to develop a mechanism to create the real-time data feeds for the algos.

EXPLAINING THE FINDING WITH THE BLACK-SCHOLES FORMULA

My graduate students and I have been looking into the mathematical mechanism of the empirical finding. One thought is to use the Black-Scholes formula to derive the relationship between option price changes for losses and gains. We started to take partial derivatives of the formula. The research is in progress. If you find a good or alternative solution to this, please let us know via e-mail: info@yeswici.com.

Since the empirical finding has been made available to the public, we have found that the variance of the loss-gain asymmetry increases over time, which may increase the p-values of the tests. This may reflect that

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the options market may self-adjust and become efficient once a systematic anomaly is detected and made known.

CONCLUSION

In this chapter, we found empirical data to demonstrate that prospect theory and option pricing are connected. In other words, we found loss aversion in option pricing on strike-on-spot prices. The finding may be repeatedly supported by statistical significance tests with real-time data. In addition, the computer algos for producing the empirical data are published.